Teachers Notes

Gravity

Worksheet Answers

Question 1:
The interplanetary scales in the Centre measure a person's weight on Earth and then calculates what their weight would be on different planets.

What is weight?

Your weight is dependent on your mass and the gravity you experience.

The strength of gravity that you feel is dependent on the planets mass and your distance from its surface.

Therefore the higher you move from the Earth's sea level the less you weigh. You weigh less in Canberra than you do in any other Australian capital!

The gravity that an object exerts is also proportional to the mass of the object. Think about the mass of the Earth and the mass of the Moon. Through intuitive thinking you can estimate that the Earth is a number of times heavier than the Moon. Therefore the gravity on Earth will be stronger than on the Moon. It so happens that the Moon has 1/6 the gravity of Earth. Therefore your weight on the Moon is 1/6 that on Earth.

In orbit around the Earth, the effect of gravity is minimal, but not zero. You are still under the influence of Earth's gravity even though it is minute. In fact there is nowhere in the Universe where gravity does not effect an object. Therefore the correct term to describe floating in space is *microgravity* (very small gravity), not zero-g or weightlessness.

The masses of the planets and their gravitational accelerations are listed below:

Planet	**Mass (compared to Earth)**	**Gravity (metres^2/ second)**
Mercury	0.0558	2.7
Venus	0.815	8.6
Earth	1.0	10.0
Moon	0.0123	1.6
Mars	0.107	3.7
Jupiter	317.89	26.4
Saturn	95.15	11.7
Uranus	14.54	9.2
Neptune	17.23	14.4
Pluto	0.0017	0.5

To calculate your weight on various planets you multiply your weight on Earth by the relevant gravitational value. You must then divide by 10 as the original value is in the unit Newtons. **Note**: Newtons are not taught to students until Year 10-11 in physics, along with the difference between the terms mass and weight. These are discussed in the appendix.

Example of calculating weight on Neptune:

The answer to the second part of the question should be the same for anyone, no matter what they mass is;

Lightest	Pluto	Moon	Earth	Jupiter	**Heaviest**

It is interesting to note that this is also the same order you would get if asked to list these planets in order of their own mass.

Question 2:

Gravity Well

Objects such as satellites and planets stay in orbit due to gravity. The gravitational force exerted on an object prevents it from travelling off a tangent path. Einstein, in his theory of general relativity, assumed that a gravitational field from a planetary body is similar to an object pushing down on an elasticised surface. Satellites will then orbit around the object as a result of the sink-like shape of the surface. They will be continually drawn into the centre until they lose their momentum and collide into the object.

As the marble's orbit draws towards the middle of the well it's speed increases. It does this because of it's lose in potential energy. Potential energy and its transfer is best described by the following example.

A ball is lifted from the ground to a height above the surface. At the instant the ball is released it has a certain amount of potential energy (or stored energy). As gravity takes hold of the ball it's potential energy becomes kinetic energy (moving energy). By the time the ball has hit the ground it has lost all of its potential energy and is has a lot of kinetic energy (it is moving at its fastest).

So as the marble is drawn into the centre of the well it gives up potential energy to become kinetic (moving) energy. This explains why planets such as Mercury and Venus, which are close to the Sun, travel faster in their orbits then Neptune or Pluto. It also helps to explain Kepler's third law of orbital dynamics. The diagram below demonstrates this law. When an object is at its closest point (perigee) to its parent it is travelling at its fastest, when it is at its furthest (apogee) it is at its slowest. You can use this concept to discuss the orbits of comets.

You can also use the gravity well to exhibit to demonstrate gravity assist. Deep spacecraft use this to ‘bend’ their path when travelling close to a planet. If the path is bent away from the Sun, it may help it leave the solar system (such as Voyager 1 and 2).

So what keeps the marbles from spiraling immediately into the hole? Their initial speed. If you allow the marble to drop without any sideways motion, it will drop immediately.

Below are some examples of orbits that can be achieved with the gravity well.

Question 3:

The concept of microgravity was discussed earlier in question 1. As a reminder;

- *the effect of gravity reduces the further from Earth you are.*
- *you cannot escape the effects of gravity anywhere in space (no such thing as zero-g).*
- *microgravity (tiny gravity) is experienced by objects in orbit around the Earth.*

Images of astronauts floating inside spacecraft can be found in books and videos on space. To recreate these images for the Apollo 13 motion picture, a replica of the capsule was placed inside an aircraft similar to the ‘Vomit Comet’ used by NASA to train their astronauts in a microgravity environment. The aircraft flies to a high altitude and then dives at a rapid rate to simulate microgravity. This effect is similar to when an elevator commences its downward trip and you fell lighter for a short period.

So what effect does microgravity have on astronauts and how would it effect your daily routine?

Eating: Meals are served in a special tray which separates the different food containers and keeps them from lifting around in the cabin. The trays holding the food are attached to the crew member's legs or a surface with adhesive straps, removing the need for a table and chairs.

Studies have shown that despite microgravity, most foods can be eaten with ordinary spoons and forks as long as there are no sudden starts, stops or spinning.

Sanitation: Because of microgravity, water droplets would float about in the spacecraft. This can not only be a nuisance but also potentially hazardous to equipment and crew. Eating utensils are cleaned with wet wipes which contain a strong disinfectant.

Astronauts have sponge baths in space using water which can be set between 18 and 35 degrees Celsius. They use a toilet which utilises airflow and suction to direct their waste which is either stored or released into space. There is no washing machine on the Space Shuttle so astronauts change their clothes every two days and seal them in plastic bags.

Shaving is done with convential shaving creams and razor blade and cleaned off the face with a disposable towel.

Recreation and Sleep: Just as on Earth, recreation and sleep are important to good health in space. A scientifically planned exercise program is provided to astronauts, largely as a countermeasure for cardiovascular deconditioning and atrophy of muscles in a microgravity environment.

To keep things in place astronauts use Velcro. Information on Velcro is included in the Appendix.

Question 4

How high you can jump is related to how much force you can use to push off from the ground. Obviously the more you weigh the more force you need to push off the ground.
Astronauts walking on the Moon carried backpacks which weighed more than xxx kg on Earth. However on the Moon they felt more like xx kg. Therefore they could jump quite high.
Remember from Question 1 that the Earth's gravity is six times that of the Moon and therefore our weight on Earth was six times that we felt on the Moon. Well this means that we can jump six times higher on the Moon than on Earth.

Using the information regarding gravity from Question 1, how high would you be able to jump on each planet? (Below is an example for Pluto)

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Weight on Pluto  = 60kg x 0.5 / 10
                 = 3kg
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So our weight on Pluto is 20 times less than on Earth. Which means we can jump 20 times higher. If you can jump 30 cm on Earth, then you can jump 600 cm or 6 metres on Pluto!